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Chapter 7

ENVIRONMENTAL CONSIDERATIONS IN CHANNEL DESIGN, INSTALLATION, AND MAINTENANCE

Introduction

A channel improvement project causes a change in the surrounding environment. The change may be abrupt or gradual; localized or broader in impact; biological, social, or cultural in nature. Whatever the changes they must be recognized and considered in arriving at the decision to modify a channel. The optimum channel improvement project is one that is based upon a careful assessment of the functional demands of the project, the needs for protection and enhancement of affected resources, and a justification that considers environmental and economic values.

The information presented here provides guidance for the proper recognition, protection, and enhancement of the affected fish, wildlife and recreation factors, during the planning, design, installation, and maintenance of channel projects.

Scope

The decision to develop a channel project will be made only after careful consideration of the impact of the project upon the environment. Once the decision has been made that a channel project is necessary, it is then equally important that the channel designer, builder, and those responsible for maintenance recognize the environmental factors that may be affected by the project. All those involved must know the techniques and measures available to protect and enhance these environmental values. This is the primary purpose for the material that follows.

Fish, wildlife and recreation factors are listed and described. Additional factors will need to be identified in local areas. The factors have *not* been rated or priorities assigned. This is the job of the appropriate specialist; i.e., engineer, biologist, forester, agronomist, range conservationist, geologist, recreation specialist, landscape architect, naturalist, etc. The development of the design requires a joint effort by all the concerned disciplines and the sponsors of the project. The final product then will result in minimized detrimental effects and, when possible, in the enhancement of some of the factors. There may be occasions when the decision to install a channel project may have to be reconsidered after all the factors are carefully evaluated.

The techniques and measures are presented to provide guidance in the development of the project in a manner that will protect or enhance the

environmental factors identified as being affected by the project. These techniques and measures are not criteria. The features or factors under consideration in a given area generally will dictate the criteria for the project. The designer, builder, and those responsible for maintenance in their use of the various techniques and measures must constantly be aware of the functional, economical and environmental aspects of the project.

The functional and economic aspects of a project cannot be separated from the environmental aspects. Drainage, flooding, vector and phreatophyte problems, and the economical aspects related to these problems, also are critical "environmental factors." They must be given consideration at the time the decision is made on the need for a channel.

A. Wildlife Resources

The fundamental needs of wildlife are food, cover, and water. Food is needed at all seasons of the year, but the types of food vary between seasons. Spring nesting and winter escape cover are critical items for most species. Seldom can a wildlife species find its needs in a single vegetative type. Thus, a mixing or interspersion of vegetative types is important within the daily cruising range of a particular species. One or more important elements of wildlife habitat always are found along or adjacent to streams. Frequently, critical woody cover is present next to the stream.

The needs for food, cover, and water vary depending upon the species. Guidelines for meeting these needs should be established by States or areas. (See Appendix D. for sample.)

B. Fish Resources*

1. Water quality is a limiting factor for fish production. The individual States have established water quality standards in line with national guidelines. The following items affect fish species suitability, production, and survival.

   a. Temperature is an important physical factor. Summer water temperatures commonly vary as much as 10^{o} in a 24-hour period. In general, summer temperatures should be between 50^{o} to 70^{o} for cold-water species. Egg hatching success is best for trout between 45^{o} to 55^{o}. Warm-water species need summer temperatures between 70^{o} to 90^{o}.

      Removal of shade tends to raise water temperatures while the maintenance of vegetation for shade may keep the water cooler. Water temperature is raised when velocity and depth are reduced. Water temperature may be affected by release of water from upstream impoundments.

* See Appendices B and C for Fish Stream Investigation Guides.

b. Turbidity caused by inorganic material, such as clay, is detrimental to fish production. Such material destroys spawning areas by sedimentation and reducing growth of bottom organisms. Adult fish generally can withstand high levels of turbidity for short periods of time, but prolonged exposure may cause mortality.

It is reported that turbidity as high as 245 mg/L is not harmful to fish. In fact, fish thrive in water with turbidities that range over 400 mg/L and average 200 mg/L. Turbidities of 3,000 mg/L are considered dangerous to fish when maintained over a 10-day period. Trout eggs were destroyed with 2,000 mg/L turbidity for six days. Symptoms of fish stress appear as turbidity approaches 20,000 mg/L; death between 50,000 and 200,000 mg/L. At turbidities causing death, the opercular cavities were found to be matted with soil and the gills had a layer of soil in them.

c. Oxygen requirements for subsidence of fingerling and adult salmon and trout are about 6 p.p.m. dissolved oxygen. Incubating eggs require a minimum of 8 p.p.m. Warmwater species require about 3 p.p.m. Water at or near oxygen saturation, for its temperature and elevation, is always satisfactory. Oxygen is put into water by direct absorption from the atmosphere, photosynthesis of growing plants, and by tumbling action of stream or waterfalls and turbulence generated at drop inlets or drop spillways. Turbidity, reduced flow, and non-tumbling action reduce oxygen.

d. Carbon dioxide is another of the basic factors determining productivity of waters. It is necessary in photosynthesis and for keeping minerals, such as calcium, in solution. High carbon dioxide levels reduce the ability of fish to take up oxygen and to dispose of carbon dioxide from the body. Concentrations of carbon dioxide should be kept below 25 p.p.m.

Carbon dioxide is put in water by direct absorption from the atmosphere, decomposing organic matter, and respiration of plants and animals. It is removed by photosynthesis, agitation of water, evaporation, and rise of bubbles from depths.

e. pH is a measure of the acid intensity in water. The scale of reading is from 0 to 14. Optimum fish production lies between 6.5 and 8.5. Values below 5 and above 9 affect the ability of fish to take oxygen from the water source. Water pH is changed if an acid layer of soil is exposed in stream bottom or sides.

2. These stream channel features affect fish production, species suitability, and survival.

   a. Bottom Material - The bottom material of a stream is important from the standpoint of food production and natural spawning. The following yield in grams of food per square foot in terms of different stream bottom m materials has been recorded: silt - 3.07; cobble - 2.47; coarse gravel - 1.51; fine gravel - 0.93; and sand - 0.1.

      Coarse and fine gravel beds in riffles are best for trout to deposit their spawn successfully. Most warm-water fish spawn in sand or silt beds in water less than 3 feet deep and with little or no current.

   b. Water Types

      (1) Riffle - Section of stream containing gravel and/or rubble, in which surface water is at least slightly turbulent and current is swift enough that the surface of the gravel and cobble is kept fairly free from sand and silt.

         Riffles are essential for trout spawning and food production. Riffles should occur at intervals equal to every 5 to 7 channel widths. The current in the riffle should be swift enough to carry away sediment. The bed material in riffles should be larger than in pools so as to provide for aeration of the water. A water depth of 6 inches is desirable.

      (2) Pool[1/] - Section of stream deeper and usually wider than normal with appreciably slower current than immediate upstream or downstream areas and possessing adequate cover (sheer depth or physical condition) for protection of fish. Stream bottom usually is a mixture of silt and coarse sand.

         Pools are valuable as resting and refuge areas. Some surface feeding also is done.

      (3) Flat[1/] - Section of stream with current too slow to be classed as riffle and too shallow to be classed as a pool. Stream bottom usually composed of sand and finer materials with coarse cobbles, boulders, or bedrock occasionally evident.

      (4) Cascades or Bedrock - Section of stream without pools, the bottom consisting primarily of bedrock with little cobble, gravel, or other such material present. Current usually faster than in riffles.

[1/] Warm-water streams normally contain only these water types.

c. Stream Side Vegetation - This item pertains to the relation of vegetation to stream shade and fish shelter. Low shrubs and grasses provide shade for small streams, but do not over-shade them. Such vegetation does not clog streams by falling in the water, and it provides hiding cover for fish if allowed to hang over the bank into the water.

Trees are necessary for shade along streams over 30 feet wide since low shrubs and grasses shade only a small portion of this width.

An ideal situation, along small streams, is enough trees for aesthetic purposes and low shrubs and grasses providing shade and cover. Along large streams, trees for about 40 percent of the stream length, on both sides should be present. There probably are situations where the presence of trees well back from the water's edge furnishes shade almost as good as comparable ones closer to the stream. This would be true especially on the east side of north-south flowing stream and the south side of east-west streams.

d. Velocities - Tolerable water velocity for fish is governed by several factors, chiefly, by the species of fish, size of fish, and the distance and frequency of resting areas. Boulders, pools, deflectors, etc. provide resting areas.

C. Recreation Resources

There are numerous opportunities for recreation along and in channels. Many of these opportunities have been discussed under the heading of wildlife, fish, or aesthetic resources.

For optimum use a recreation resource must satisfy several key factors:

1. Proximity - All recreation activities are distance-related with respect to the user's home. Generally the greater the population within a 50-mile radius (or an hour's drive), the more the area may be used.

2. Access - The public road system needs to provide access to the potential recreation resource. The degree of access of the area can be gauged by determining the portion that is within one mile of an all weather road. Again, the greater the degree of access the more likely the recreation area will be used.

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3. Ownership - The ownership and land-use pattern of the area have a bearing on the potentials for developing recreation opportunities. The area must be of sufficient size to support a public recreation activity. The landowner must be interested. The area will have to be accessible to the public for heavy use. Sometimes the resource will be used by the landowner and his family.

Specific factors for each activity are:

1. Fishing - Stream fishing has a special quality for some fisherman. All of the environmental factors listed under "Fish Resources" are essential if fishing opportunities are to be provided.

   Many factors besides the abundance of fish and accessibility enter into stream fishing quality. The unique scenic setting, sounds of nature, the sight of a riffle or pool, the wooded reach, the open meadow, and overall diversity of a landscape are qualities appreciated by the stream fisherman and enjoyed by many others. Streams that are partially brush and tree lined offer the fisherman the opportunity to exercise his skill.

2. Hunting - Hunting opportunities often are enhanced by the presence of streams or channels. In some localities the vegetative cover along channels (brush and trees) provides the only cover available for hunting. The brush and trees provide, for some species, the only avenues for hunting, escape cover from predators, or the opportunity for protected movement. The grasses and legumes provide the essential nesting cover required for ample populations. All of the environmental factors already described under "Wildlife Resources" are essential if the hunting opportunity is to be established.

   The combination of food, cover, and water enhances the opportunities for hunting success.

   Channels and the accompaning marshes offer opportunities to hunt many species of waterfowl, rail, and woodcock. In some areas they provide the only habitat for these species.

3. Swimming - Swimming in streams and channels is an activity practiced in many parts of the country, particularly if ponds and lakes are relatively scarce. Desirable environmental factors are good water quality, pH between 6.5 and 8.3, coliform count below 800, clear water with minimum in flow of 650 gallons of water per bather per day (number of bathers $\div$ 1,000 = inflow cfs). State regulations may require higher standards. Shade and desirable soils (sands) will enhance the desirability of the area.

   Stream "pools" may be developed fully with all facilities (bathhouse, beach, etc.) present or they may be simply the local swimming "hole."

Depth should be at least 5 feet, greater if diving is permitted. The shore line should have a slope of less than 10 percent, 2-4 percent is best.

4. Boating and Canoeing - Boating streams should be at least 2 feet deep for rowboats or 3 feet for boats with outboard motors. A good width is at least 2-1/2 times the length of boat allowed. Narrower streams, however, can be utilized. Stream channels with minimum depths must be free of obstructions.

   Canoeing streams may have depths as shallow as 6 inches for short stretches or 18 inches for a major portion. Canoeists are not adverse to portaging (carrying) for short stretches where water is too shallow. Good widths are 17 feet, but widths of 6 feet are acceptable. Some authorities recommend an average flow of 100 cfs in order to be suitable but this is dependent upon depth, width, and gradient. While many canoeing streams have white water and pools in combination, flat water streams attract thousands of users for canoeing and boating alike.

5. Hiking and Walking - Many of the same characteristics that enhance a canoeing or boating stream are desirable for hiking along a stream. Cascades, riffles, white water and pools, shrubs and trees with a variety of color and shape add to the aesthetic value.

   Over-water walkways and bridges which permit extensive observation are interesting features. A trail should be approximately 4 feet in width, sufficient to allow two people to walk side by side. A grade of 10 percent or less is recommended.

6. Painting and Photography - The thousands of photographs and paintings depicting landscape scenes with streams attest to man's interest in viewing his environment. Natural curves, a variety of landscapes, water courses meandering through a variety of vegetative types and vistas all provide professional and amateur artists with ample subject matter.

7. Camping - The environmental factors previously discussed may be used as guides. Vacation camping may be a profitable recreation activity if other recreation opportunities (fishing, swimming, boating, etc.) also are available. Transient campground may be feasible without these activities if the size is within 3 miles of a major highway. In either case the necessary land area is 10-15 acres. Soils in the area should be suitable for septic tanks and roads. An adequate potable water supply should be available. Characteristics that limit an area's usefulness for camp sites are susceptibility to flooding, impermeable hardpan layers, shallow soil over bedrock, restrictions to natural drainage, erosion hazard, and inability to support and sustain vegetative cover. Slopes should be less than 15 percent, preferably less than 8 percent.

8. Botanizing - On occasion, an area adjacent to a water course may be of particular interest to botanists and other nature lovers. The species of plants may, but need not be, of rare or exotic nature.

9. Bird Watching - The environmental factors discussed under "Wildlife Resources" should be used in determining whether the opportunities for bird-watching exists. The thousands of birdwatchers in the country often visit water courses during their bird counts. In some areas the plant species may compose a specialized habitat for a particular species of bird. Fields of one crop reduce the number and species using the area. The shrubs and trees bordering a channel have added value in crop areas. Landscape variations are much more attractive to songbirds than areas of a single crop.

10. Specimen Collecting - Artifacts from cache pits or Indian mounds, fossils, decorative rocks, or desirable mineral specimens are of interest to a number of people, institutions, and agencies. Collectors also may find driftwood, burntwood, and tree roots of value or interest.

A guide for evaluating channels for general recreation development is included in Appendix A. See Fig. 1

Protection and Enhancement Techniques and Measures

Design

1. Alignment, Capacity, and Grade - Channels generally will follow existing alignment except where stability, environmental, or cost factors clearly dictate an alternative course. For instance, a section of the channel or floodway may be relocated in order to bypass important fish or wildlife habitat.

   Natural streams and constructed channels need to convey water discharges of all magnitudes from base flow through floodflow without significant damage to the channel or to fish habitat. In order to protect a desirable existing stream channel, higher frequency floodflows could be carried out of banks or on a separate alignment. As the floodflow channel would be dry most of the time, it could be designed to include farming or reforestation within the right of way.

   Water often is used as a receiving medium for various waste discharges and yet its quality must be maintained so that it is suitable for instream recreational uses as well as out of stream needs for municipal water supply, irrigation, cooling, washing, and dilution. Reservoir releases of stored water can provide low flow augmentation to prevent waste discharges from exceeding acceptable concentrations and to provide recreation and fish habitat water requirements. Oxbow and wetland flood storage, with controlled releases, also can be used for this purpose.

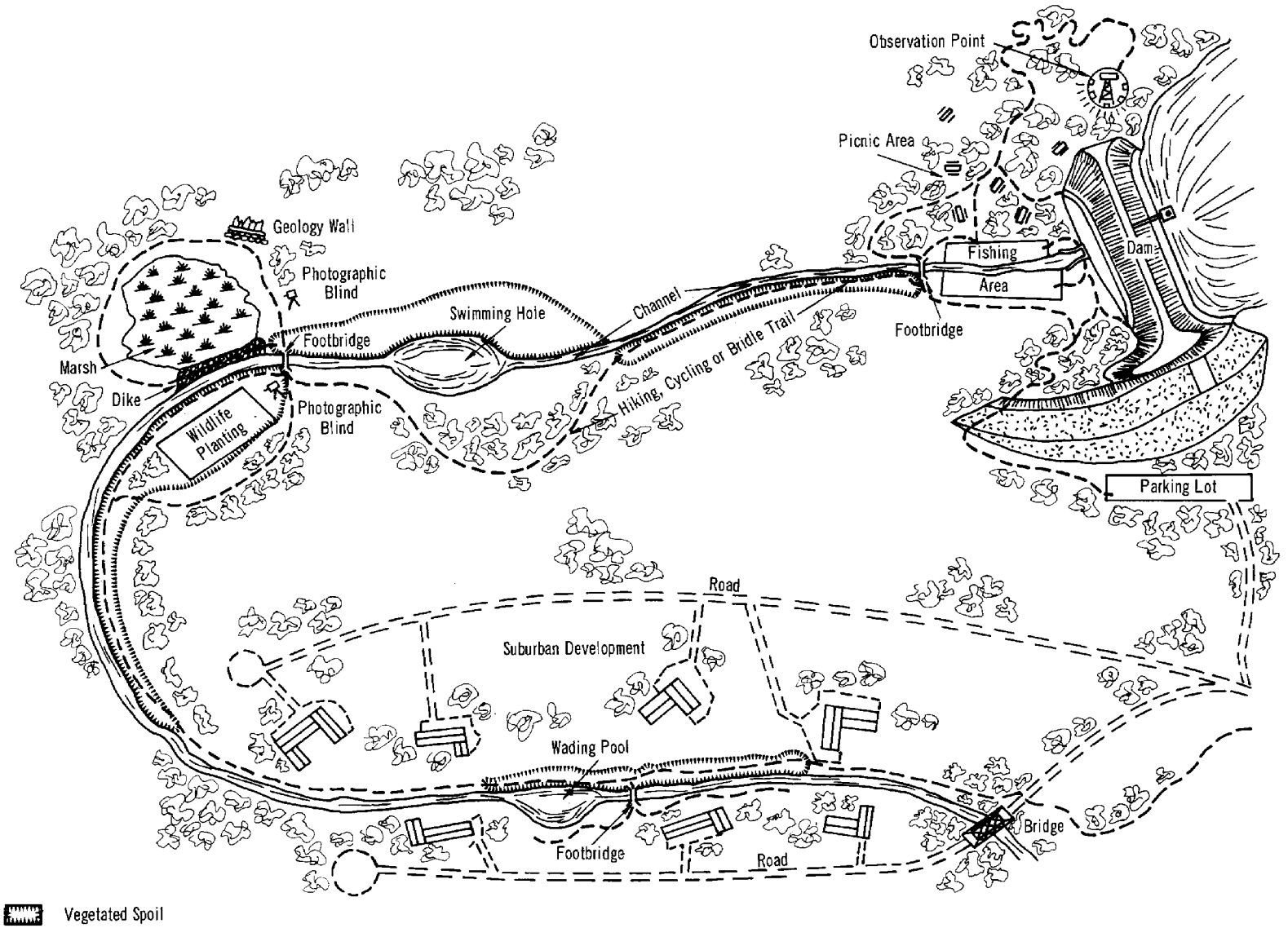


Figure 1 CHANNEL RECREATION POSSIBILITIES

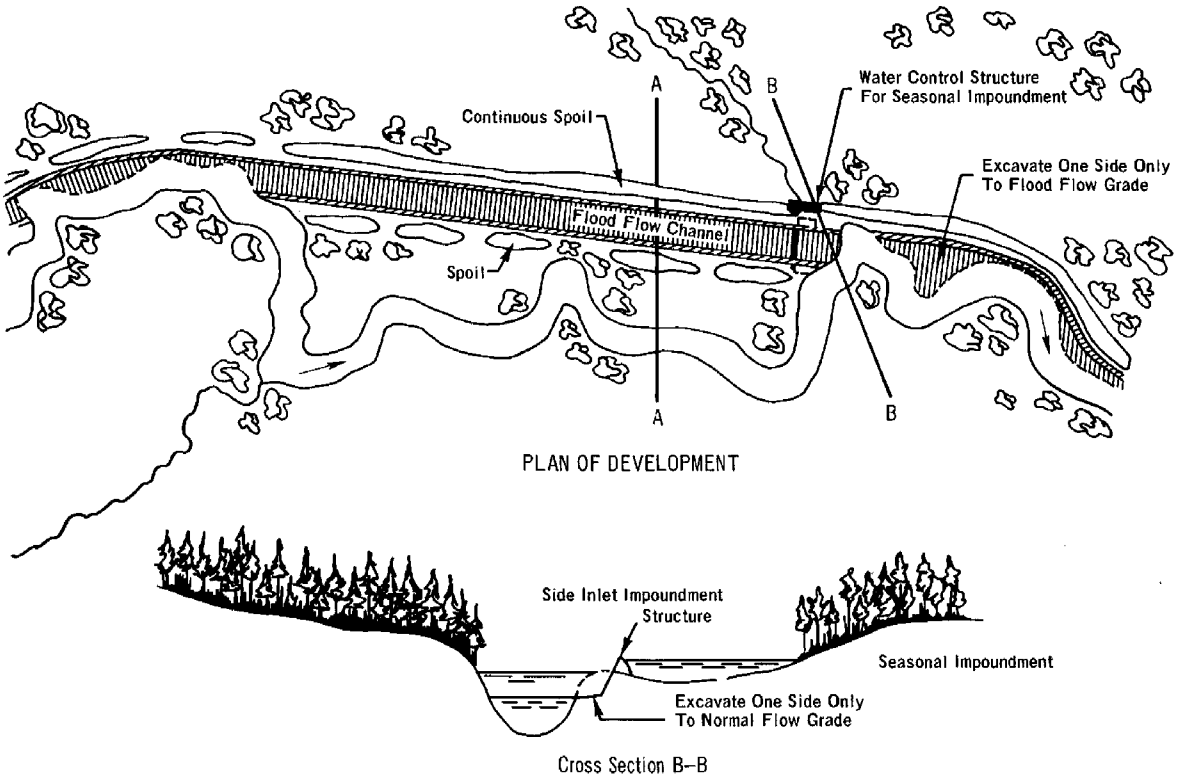
Sediment loads delivered to the channel by tributary streams or other sources need to be controlled as part of the overall design. A stable channel has a limited sediment carrying capacity and downstream uses of the water may necessitate further limitation of sediment load. Sediment traps may be needed at delivery points or at intermediate points along the channel to provide the required water quality and stability.

In certain reaches, the channel slope may need to be flattened to obtain stability in highly erosive soils or can be steepened to make maximum use of erosion resistant soils. Where gravel armoring or riprap is needed, or just available, full use should be made of its ability to withstand higher velocities. The channel slope variations and rock protection will allow for the inclusion of pools and riffles and also provide control of meander development.

2. Channel Section - The low flow channel cross section should approach a natural stream condition. (Figure 2) The side slopes and bottom width can be allowed to vary to take advantage of existing conditions. Where possible, the side slope on the outside of the channel curve could be steepened and the side slope on the inside of the channel curve flattened to duplicate a naturally developed sinuous waterway. Use the onsite large boulders in riprap sections or at selected points for fish habitat development. Large slab rocks or boulders can be used to create near vertical banks and on trout streams for wing deflectors and bank cover devices to improve the fishing potential. (Figure 3) The channel bottom width can be varied in conjunction with the bed slope to aid in the development of deep pools, cascades, low velocity sections, and sections of high velocity rips that would simulate natural conditions and also take advantage of localized variations of in-bank capacity and stability. Width restrictions also could be satisfied in this manner.

   Figure 4 shows the cross sections, meander pattern, bed contours, and bottom profile that can develop in a natural stream. The meander parameters shown are average values but could be used for preliminary proportioning and alignment of a constructed channel. Other factors, such as discharge, character and amount of bed load, general valley slope and the resistance of bed and banks to erosion, also need to be considered to develop the final layout.

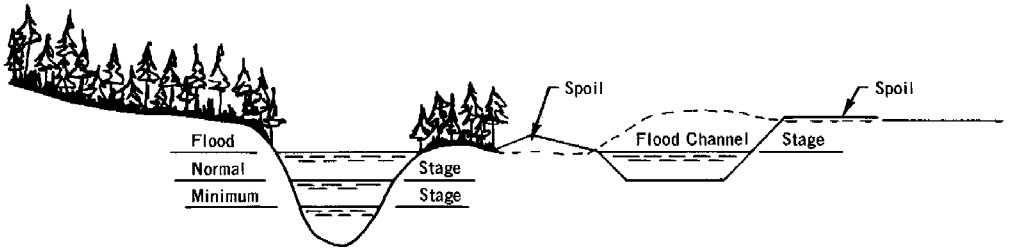
3. Spoil Placement - Channel excavation spoil should be utilized in a manner most appropriate for the controlling reach conditions. In general, excavated materials should be placed so as to reduce to a minimum the required clearing and disturbed areas and to provide wildlife habitat. (Figure 5) The template sections shown on the drawings and the specifications should provide guidance as to typical sections, approved spoil disposal methods, maintenance limits and construction limits.



PLAN OF DEVELOPMENT

Cross Section B–B

ONE-SIDED CONSTRUCTION FOR ADJACENT STREAM CHANNEL & FLOOD FLOW CHANNEL



Cross Section A–A

UNDISTURBED STREAM CHANNEL & SEPARATE FLOOD FLOW CHANNEL

Figure 2 SEPARATE LOW FLOW AND FLOOD FLOW CHANNELS

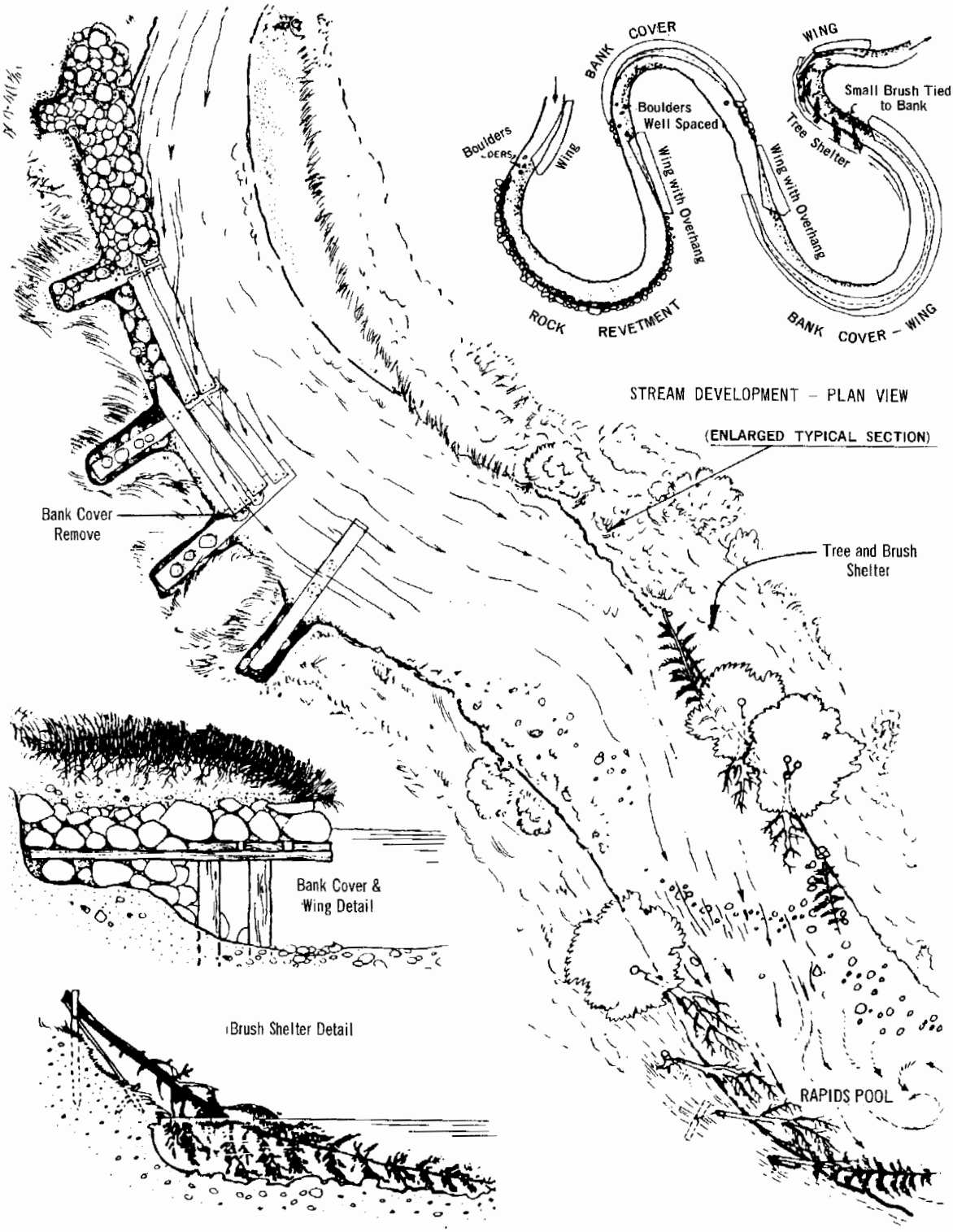
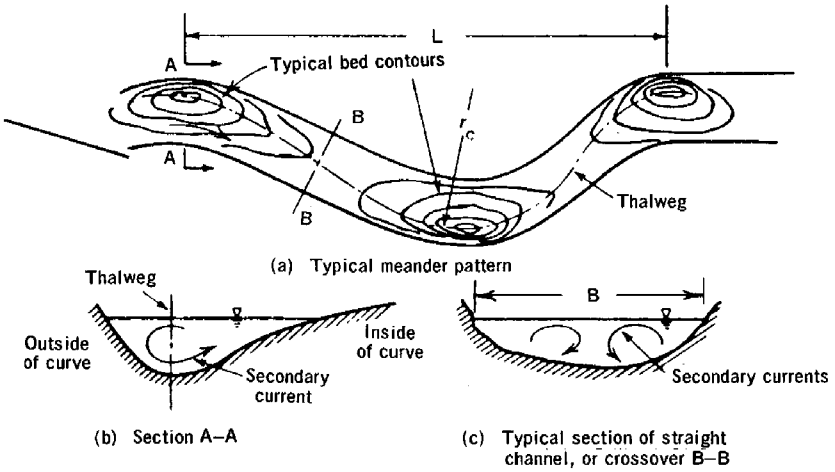


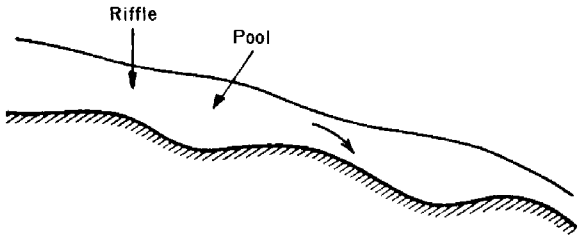
Figure 3 FISH HABITAT DEVELOPMENT



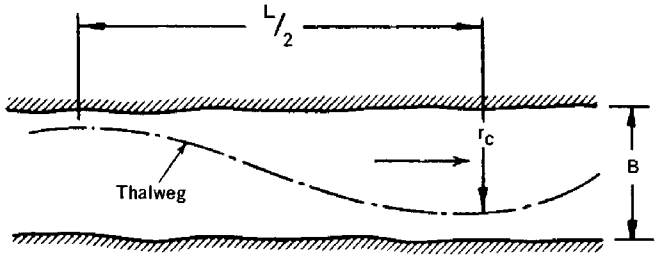
(a) Typical meander pattern

(b) Section A–A

(c) Typical section of straight channel, or crossover B–B



(d) Pool–and–riffle formation (VERTICAL MEANDER PATTERN)



(e) Concealed meander pattern in a straight channel

r_c = radius of curvature in Thalweg

APPROXIMATE MEANDER PARAMETERS

$\frac{L}{B}$ = 7 TO 11

$\frac{r_c}{B}$ = 2 TO 3

Figure 4 NATURAL CHANNEL – MEANDER PATTERNS WITH POOL AND RIFFLE DEVELOPMENT

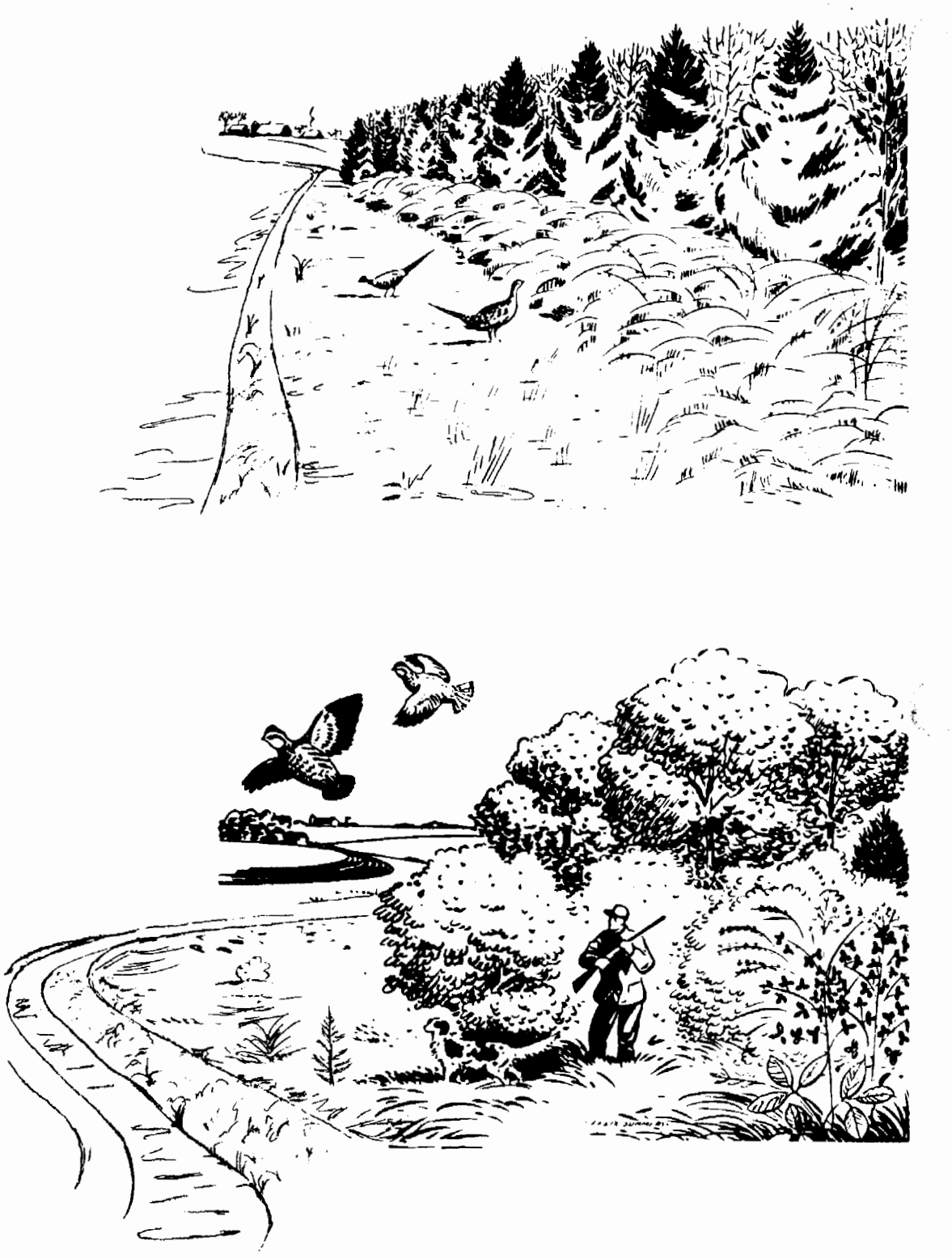


Figure 5 SPOIL BANK DEVELOPMENT FOR WILDLIFE HABITAT

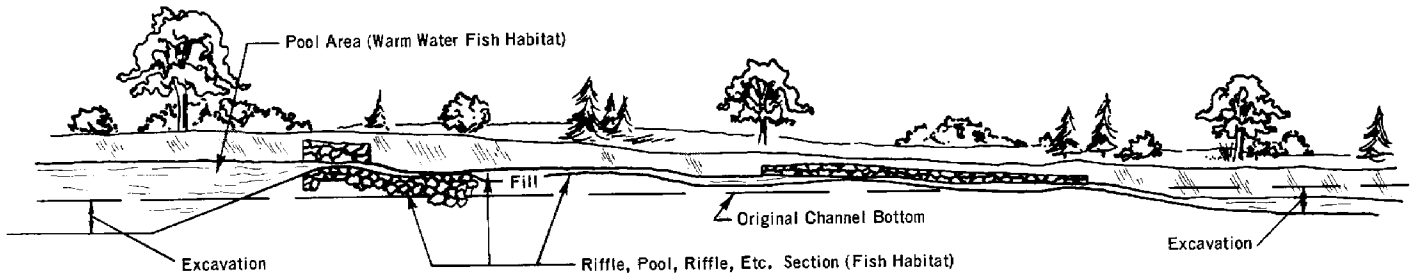
4. Structural Measures - Channels with flat enough gradients so that stability is not a design problem could, if desirable, be laid out in pond-riffle-pool manner. The additional grade provided by ponding would allow the inclusion of a series of riffles and pools that could add to the fish habitat. See Figure 6.

5. Vegetation

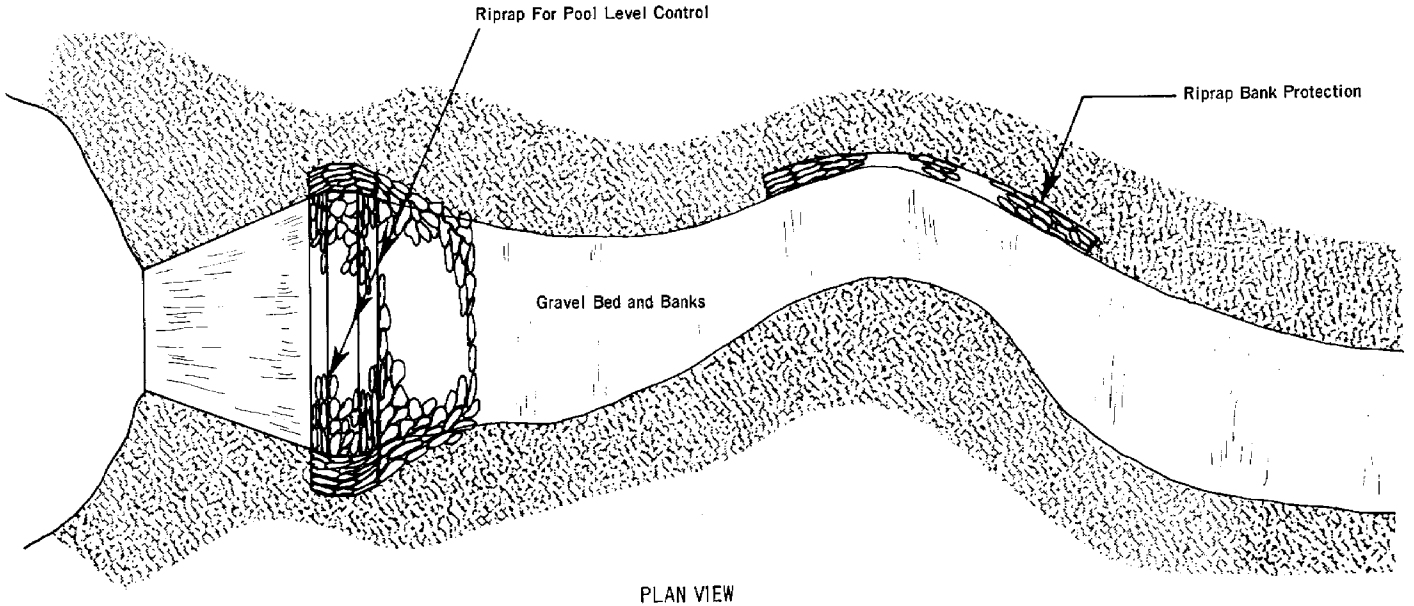
   a. Wildlife habitat seedings and plantings can be used outside the channel section, on the spoil sections or in odd corners of suitable size where the wildlife potential can be enhanced and the disturbed areas stabilized. Wildlife habitat mitigation areas, when included, and the normal habitat seedings can be laid out in discontinuous blocks, irregularly sized to provide a maximum of edges.

   b. Recreation areas could be selected for special treatment that would greatly add to the utility of the project. Functional planting can be used to screen noise and direct pedestrian traffic.

      Figure 1 shows some examples of activity areas that might be included along a channel. A hiking, cycling, or bridle trail along the berm, or stream side fishing supplemented with a few picnic tables for the rest of the family. A dike to preserve a marsh enhanced by a wildlife planting. A swimming "hole" for light use or a wading pool in a suburban development. "Green" areas through suburban areas can be developed into playgrounds or neighborhood parks. Long channels with sufficient depth may be used for canoeing.



CHANNEL PROFILE – BUILT IN GRADE AND BOTTOM CONFIGURATION



PLAN VIEW

Figure 6 CHANNEL SEGMENT WITH POND, RIFFLE, POOL LAYOUT

APPENDIX A

Evaluating Channels for Recreation Developments

A copy of the chart and work sheet used in this approach follow. The use of this approach requires a cursory on-site investigation. Ratings are determined on the basis of judgment and estimations.

It should be noted that this evaluation is for a "general" recreation development. Evaluation of a site for specific recreation activities entails consideration of many additional key elements or a change in the criteria already outlined. Water flow criteria, for example, would be different if swimming, canoeing, or hiking were the specific activities under consideration. Additional key elements, such as length of channel, size of adjacent land area, width of adjacent land area, soils, depth of water are some additional key elements required for specific activities. Recreation developments should be planned to preserve and intensify the landscape character. Planning should not introduce a disturbing, inharmonious item into the landscape, whether it is a facility or an activity. The planner should ensure that the planned project comprises a complex of functions related to the best features of the site. For this reason, evaluation and planning for specific recreation activities should be undertaken by the appropriate specialist.

EVALUATING CHANNELS AND ADJACENT AREAS FOR RECREATION DEVELOPMENTS

Key Elements	Multi-plier M	Rating (R) High 4	Moderate 3	Fair 2	Poor 1
Water Quality	4*	No pollution coli count below 200	ph 6.5-8.3 coli count 200=600/100 ml	ph 8.3-9 or 5-6.5 coli count 600=800/ 100 ml	ph 9 + or 5 - coli count 800 +/100 ml
Aesthetics (vista, natural attractions near-by, visual appear-ance of channel)	4*	Excellent	Good	Fair	Poor
Water Flow	4*	Little variation with riffles and pools	Little variation	Inter-mittent	Lacking sufficient flow during primary use period
Adjacent Land Flora	3	Wooded or open with 12" trees forming a 10-20% canopy	Open with grass and small trees form-ing a 10-20% canopy	Open with grass and brush	Open - grass only
Distance From Users	3	Under 1/2 Hr.	1/2-3/4 Hr.	3/4-1 Hr.	Over 1 Hr.
Distance to Surfaced Road	2	Under 3 miles	3-5 miles	5-10 miles	Over 10 miles
Width of Channel at Normal Water Surface	2	20' +	11-19'	6-10'	6' -

Formula $\Sigma(MxR)$ = Score

Maximum Possible Score 88

High Potential	67 - 88
Medium Potential	45 - 66
Low Potential	22 - 44

* If any key element with a multiplier of 4 is rated as "Poor" (1) that element must be considered limiting. Further consideration of other key elements is unnecessary. The area is generally considered unsuitable for recreation development.

SAMPLE WORKSHEET

EVALUATING CHANNELS AND ADJACENT AREAS
FOR RECREATION DEVELOPMENTS

State _____ County _____ Township _____

River Basin _____ Watershed _____

Location or Job No. _____

Key Elements	Multiplier (M)	x	Rating (R)	
Water Quality *	4	x		=
Aesthetics *	4	x		=
Water Flow *	4	x		=
Adjacent Land Flora	3	x		=
Distance From Users	3	x		=
Distance to Surfaced Road	2	x		=
Width of Channel at				
Normal Water Surface	2	x		=

Total Score _____

Maximum Possible Score 88

High Potential	67 - 88
Medium Potential	45 - 66
Low Potential	22 - 44

* If any key element with a multiplier of 4 is rated as "Poor" (1) that element must be considered limiting. Further consideration of other key elements is unnecessary. The area is generally considered unsuitable for recreation development.

APPENDIX B

Sample
Fish Stream Investigation Guide

Introduction

This guide provides a systematic approach to fish stream investigation.

Ten stream features are used to obtain a biological rating and six use factors are used to obtain a use rating.

Each stream feature is recorded and rated on a field work sheet, using predetermined criteria. The ten features have been assigned importance factors based on their individual importance to the total stream character. The final rating is weighted average of the individual stream features.

The use rating is a judgment based on six items related to fishing.

Instructions

Heading - Show watershed, major water courses, and important tributaries.

Biological Investigation

1. Designated Reaches - The appraiser should divide the stream into reaches from mouth to upper limit. The two designated points setting the limits of each reach should be easily identifiable on the ground by designated roads, natural markers, or points selected due to some physical land or stream characteristic. (No rating)

   Length - The length must be measured in feet. (No rating)

   a. Average width (ft.) is measured at normal flow or depth.
      Importance factor of 2.
      Rating - 1 point for each foot of average width. (Maximum 10)

   b. The acreage of the stream is calculated by multiplying the length (ft.) by average width (ft.) and dividing by 43560.
      Importance factor of 3.
      Rating - 3 points for 1/2 acre or less (warm water - 1 acre or less)
      3-5 points for 1/2 acre to 1 acre (warm water - 1-2 acres)
      6-10 points for 1 acre plus (warm water - 2 acres plus)

(Increase or decrease one point for each 1/4 acre) (warm water - 1/2 acre)

c. Flow - Constant flow is year-long and intermittent only a portion of a year.
Importance factor of 10.
Rating - Intermittent flow
2 points base score. Subtract 1 point for each 15-day period (or fraction thereof) without flow.

Constant flow
2 points base score. (Maximum 10)

Cold - Add 1 point for each 1 inch of average flow depth in riffle.

Warm - Add 2 points for each 5 inches average flow depth in riffle.

2. Water chemistry is measured in parts per million. Temperature is recorded in degrees F.

Water chemistry is a limiting factor and overrides all other factors if any quality condition falls outside fish requirements.

3. The pool riffle ratio is calculated by determining the feet of each reach in riffles, pools, flats, and cascades or bedrock and calculating the percent of total length. These are defined as follows:

Riffle - Section of stream containing gravel and/or rubble, in which surface water is at least slightly turbulent and current is swift enough that the surface of the gravel and rubble is kept fairly free from sand and silt. (Disregard bottom material for warm water stream.)

Pool - Section of stream deeper and usually wider than normal with appreciably slower current than immediate upstream or downstream areas and possessing adequate cover (sheer depth or physical condition) for protection of fish. Stream bottom usually a mixture of silt and coarse sand.

Flat - Section of stream with current too slow to be classed as riffle and too shallow to be classed as a pool. Stream bottom usually composed of sand or finer materials, with coarse rubble, boulders, or bedrock occasionally evident.

Cascades or Bedrock - Section of stream without pools, consisting primarily of bedrock with little rubble, gravel, or other such material present. Current usually more swift than in riffles.

The sums of a, b, c, and d should equal 100 percent.

Importance factor of 10.

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Rating - (Consider quality of pools and riffles for in-group rating.)

8-10 if pool-riffle ratio is at least 35 percent pools and 35 percent riffles.

4-8 if less than 35 percent of stream is in pools and 35 percent or more is riffles or if more than 35 percent is in pools and 35 percent or less is in riffles.

1-3 if less than 35 percent in pools and less than 35 percent in riffles (Must be in this range if intermittent flow.)

4. The water source - Place a check mark to indicate water sources for each reach. Number of sources probably will decrease as one progresses upstream.

Importance factor of 5.
If source is springs and seeps rate 10.
If source is runoff drainage rate 3.
If source is lakes or ponds rate 2.
Any combination - 5.

5. Dominant vegetation - This item pertains to the relation of vegetation to stream shade and fish shelter, not wildlife habitat. Record in feet for right and left bank.

Importance factor of 5.
Rate each side independently and average rating.
For each reach and total stream length award 2 points for each 10 percent of tree and shrub type. (Maximum 10)

6. Turbidity - Express as clear if bottom is distinctly seen through 4 or more feet of water, slightly turbid if bottom can be seen at from 1- to 4-foot depth, and turbid if bottom is only visible at less than 1 foot. (If organic stain of fertility prevents appraisal of this item, so note and disregard this item.)

Importance factor of 5.

Rating - Clear 10.
Slightly Turbid 5.
Turbid 1.

7. Sediment - This item reflects the amount of sediment deposits visible in the stream bottom. Sediment influences pool-riffle ratio, width, acreage, turbidity and possibly other factors. Therefore, it is felt the rating of these items will reflect the effect of sediment. (No rating)

8. Check all visible or detectable sources of pollution, including siltation, altering water quality.

   Water pollution (as water chemistry) is a limiting factor if severe enough to affect fish life or cause undesirable aesthetic quality.

   Final

   Multiply rating assigned to each element by the importance factor, add totals, and divide by total of importance factors.

BIOLOGICAL SCORESHEET

Stream Feature	Importance Factor	x Rating	= Score
1 a.	2	x _____	= _____
1 b.	3	x _____	= _____
1 c.	10	x _____	= _____
2 (Limiting factor)			
3	10	x _____	= _____
4	5	x _____	= _____
5	5	x _____	= _____
6	5	x _____	= _____
7 (No rating)			
8 (Limiting factor)			
	Total 40		_____ Total

= Final Grade

40 √ Total Score

The final stream grade is based on a scale of 1 - 10 (10 being the highest possible grade). A grade of less than 5 indicates a stream with a low biological value. The process identifies characteristics by reach and by evaluating them, management needs and potential can be identified.

Use Investigation

1. Fish Resources - Name species and specify category.

2. Access - This is physical access due to terrain, stream-bank vegetation, aquatic vegetation, debris, etc.

3. Public Access - Indicate 0, 1, 2, or 3 in blank.

4. Ownership - Check if public ownership, etc.

5. and 6. Fishing Pressure and Success - Record based on local knowledge, special studies, use evidence, and information in 1 through 4.

   The final rating indicates value of stream fishing area and is one of judgment made by the investigator based on the information in items 1 through 6. The present use rating may be limited by access factors and a potential use rating substituted for it if so desired.

Source References

1. Lagler, Karl F. (1952) Freshwater Fishery Biology, William C. Brown Company, Dubuque, Iowa.

2. Seehorn, Monte E. (1970) A Survey Procedure for Evaluating Stream Fisheries, 24th Annual Convention, Southern Division, American Fisheries Society, Atlanta, Georgia.

3. Unpublished - A Guide to Stream Appraisal, UD - RTSC, TSC Advisory BIOL - UD-11, 1967.

FISH-STREAM INVESTIGATION GUIDE
(Worksheet for In-Service Use Only)

Watershed:_____ Stream:_____

Tributary to:_____ Important branches or tributaries:_____ _____ _____ _____ _____

Biological Investigation

1. Designated Reaches:

			Length (Ft.)	(a) Av.Width (Ft.)	(b) Ac. - Area	(c) 1/ Flow
(1)	From	To				
(2)	From	To				
(3)	From	To				
(4)	From	To				
(5)	From	To				
(6)	From	To				
Etc.		Total				

2. Water Chemistry and Temperature

Reach	Pheno ALK	MO ALK	T. Hardness	T D S	pH	O_2	Temp - H_2O
1.							
2.							
3.							
4.							
5.							
6.							

Date_____ Time _____ Air Temperature_____ Weather _____

1/ Constant Intermittent
(with average depth)

3. Pool-Riffle Ratio

	Reach 1	2	3	4	5	6	Total	Percent
a. Ft. in riffles								
b. Ft. in pools								
c. Ft. in flats								
d. Ft. in cascades or bedrock								

4. Water Source(s)

	Reach 1	2	3	4	5	6
Runoff/drainage						
Lake/pond						
Springs/seeps						
Marshes						
Tide						
_____						

5. Dominant vegetation within 25 feet of normal water level on each side
(Note: Identify all important types)

Dominant Vegetation Types	Reach 1 R	1 L	2 R	2 L	3 R	3 L	4 R	4 L	5 R	5 L	6 R	6 L
a. Marsh/bog plants												
b. Wild grass/weeds												
c. Shrubs(understory)												
d. Trees (overstory)												
e. Pasture or hay												
f. Crop field												
g. _____												
Total												

6. Water clear, slightly turbid, or turbid:

1 _____ 2 _____ 3 _____ 4 _____ 5 _____ 6 _____ 7 _____
(Record for other than flood flow)

7. Degree of siltation: (Slight or none, moderate, or extremely heavy)

1 _____ 2 _____ 3 _____ 4 _____ 5 _____ 6 _____ 7 _____

8. Evidence of Pollution: (Check)

	1	2	3	4	5	6
a. Sewage						
b. Animal effluents						
c. Industrial wastes						
d. Eroding areas						

USE INVESTIGATION

1. Important fish resources
(Name: STK. = stocked annually; mig. = migrant (spawner); res. = permanent resident in reach)

1 _____( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	
2 _____( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	
3 _____( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	
4 _____( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	
5 _____( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____( )	_____ ( )	
6 _____( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	_____ ( )	

2. Access for fishing us U = unlimited, R = restricted, 0 = none in reach:

1_____ 2 _____ 3 _____ 4 _____ 5 _____ 6 _____ 7 _____

3. Public fishing is allowed to the approximate extent of 0 = none, 1 = less than 1/2, 2 = more than 1/2, 3 = all of rest

1_____ 2 _____ 3 _____ 4 _____ 5 _____ 6 _____ 7 _____

4. Public agency has fishing ownership, easement, right-of-way on reach:

1 _____ 22_____ 3_____ 4 _____ 5 _____ 6 _____ 7 _____

5. Fishing pressure (Check)

	1	2	3	4	5	6
High	_____	_____	_____	_____	_____	_____
Moderate	_____	_____	_____	_____	_____	_____
Low	_____	_____	_____	_____	_____	_____

6. Fishing success (Check)

Good	_____	_____	_____	_____	_____	_____
Fair	_____	_____	_____	_____	_____	_____
Poor	_____	_____	_____	_____	_____	_____

APPENDIX C

POOR QUALITY RECOGNITION GUIDE

Quality Class No.	Pool		
	Length	Depth	Shelter [1]
1	Greater than a.c.w. [2]	2' or deeper	Abundant [3]
	Greater than a.c.w.	3' or deeper	Exposed [4]
2	Greater than a.c.w.	2' or deeper	Exposed
	Greater than a.c.w.	<2'	Intermediate [5]
	Greater than a.c.w.	<2'	Abundant
3	Equal to a.c.w.	<2'	Intermediate
	Equal to a.c.w.	<2'	Abundant
4	Equal to a.c.w.	Shallow [6]	Exposed
	Less than a.c.w.	Shallow	Abundant
	Less than a.c.w.	Shallow	Intermediate
	Less than a.c.w.	<2'	Intermediate
	Less than a.c.w.	2' or deeper	Abundant
5	Less than a.c.w.	Shallow	Exposed

1/ Logs, stumps, boulders, and vegetation in or overhanging pool or overhanging banks.

2/ Average channel width.

3/ More than one-half perimeter of pool has cover.

4/ Less than one-quarter of pool perimeter has cover.

5/ One-quarter to one-half perimeter of pool has cover.

6/ Approximately equal to average stream depth.

APPENDIX D

Habitat Requirements

(The material below was developed to illustrate the type of information that the designer needs to have available. These data can be prepared for States or Regions and then can cover the appropriate species.)

Listed below are some specific habitat requirements for the more common wildlife species. These descriptions can be used to identify existing habitat, judge quality, and determine effects of modification.

1. Pheasants - A favorable land use pattern for pheasants consists of: (a) 60-80 percent in grain and seed crops, (b) 10-30 percent in grasses and legumes, (c) 5-10 percent in brush and woods, and (d) 3-5 percent in permanently protected herbaceous weedy cover.

   Crop fields ten acres or more in size, growing barley, buckwheat, corn, grain sorghum, oats, proso millet, soybeans, or wheat, should dominate the area. At least two acres of grasses and legumes (alfalfa, crownvetch, orchardgrass, reed canarygrass, sericea lespedeza, smooth brome, switchgrass, or timothy) per 100 acres should be present. Extra growth should be present on at least two 1/8 acre plots within 100 feet of a vegetative change. It is desirable to have at least one 1/2 acre strip of annual weeds per 100 acres and at least 1 acre of brushy thickets or woods.

2. Bobwhite Quail - Bobwhite usually thrive best where there are numerous small fields of grain and seed crops, interspersed with grassland, weedy patches, and brush or woodland areas. They seldom are abundant in extensive and continuous areas of cropland, grassland, or dense woodland.

   At least one-half acre of grain and seed crops (corn, cowpeas, lespedeza, millet) should be present within 100 feet of woody cover per each 100 acres of habitat or a one-half acre patch of wild herbaceous plants (panic grass, ragweed, croton, partridge pea). A combination of the two is best. Unmowed grass areas, 1/10 to 1/4 acres near food and cover, provide necessary nesting sites for a covey range. Woody cover totaling about 1 acre per 100 is necessary.

3. Ruffed Grouse - This grouse is a bird primarily of woodland edges and openings rather than dense woods. Hardwood trees should predominate. Hardwood trees, such as alder, apple, beech, birch,

cherry, mountain-ash, oaks, and poplars, should be well distributed throughout the woodland. Openings within each 200 acres of woodlands should occupy at least 1 percent of the area and not exceed 15 percent. Such openings are more valuable if a variety of vegetation, such as perennial weeds, wild grass, shrubby evergreens, and hardwood brush, grow in them.

4. Cottontails - Individual cottontail rabbits usually spend their entire lifetime in less than 10 acres of habitat. Therefore, a wide variety of vegetation on small-sized areas is desirable for good habitat. Four or five small patches (one-tenth to one-quarter acres) of grasses and legumes, wild or domesticated, in and around woody and brushy or cultivated fields, provide good food and cover. At least 50 percent of any area of rabbit habitat should be in hardwood trees and shrubs.

5. Woodcock - Habitat for woodcock may be described as a mixture of grass, perennial weeds, shrubby evergreens, and brushy thickets, generally occurring on moist soils having fairly high fertility and considerable organic matter (condition favorable to earthworm abundance).

   Brushy thickets should occupy 40 - 50 percent of the area, and should not exceed 15 feet in height. At least 500 square feet per acre of brush should be in grass and perennial weeds and brush should not exceed 2 feet in height for 50 feet around openings. Several small clumps of evergreen, shrubs near grassy areas provide nesting and brood rearing sites.

6. White-tailed Deer - This deer is an animal of forest lands broken by small clearings, lakes, swamps, crop fields, cut-over areas, pastures, hay meadows, etc., which create edge or allow sunlight to reach the ground so that shrubs and bushes will grow. Deer prefer open forest which provides plentiful understory vegetation.

   One 5-acre opening per each 200 acres of woodland provides grasses and legumes for summer and spring food. In addition, one 5- to 20-acre opening per each 200 acres of growing woodlands, shrubs, and vines increases the food supply.

7. Tree Squirrels - The fox squirrel is largely an inhabitant of mature, somewhat open, hardwood forests and woodlots. The gray squirrel lives primarily in large unbroken bottomland hardwood forests. The ranges overlap considerably, but normally one species predominates. Both species occupy two types of nests - den and leaf. Den trees provide the best protection. Two or three good den trees per acre are desirable. Nuts and acorns are staple foods; seed, buds, and fruits also are eaten. Each animal requires about a pound and a half of food per week. Nut-bearing trees should be well distributed throughout woodland, at least two per acre.

8. Non-Game Land Birds - Non-game birds include a great variety of species which are found in nearly every kind of vegetative community. These

species eat all kinds of foods, have many adaptations for nesting, feeding, escape, migration, etc. Therefore, a variety of habitats will support a variety of species. As a rule, the greater the variety of plant forms on a given tract of land, the larger the number of bird species and the more the individuals. Such areas may be grassy areas, grain and seed cropfields, weedy spots, brush areas, and woodlands. They also may be lawns, pastures, meadows, fencerows, small woodlots, barnyards, pond edges, etc.

9. Waterfowl and Other Wetland Birds and Muskrats

a. Ducks (mallard, pintail, black duck, teal, wood duck): Ducks require several different vegetative types and water conditions for nesting, rearing broods, adult moult, and feeding:

(1) Courting, pairing, and mating (mid-winter and early spring, before nesting activities) require little or no vegetative cover, as these activities generally are performed on small open-water areas with bare shorelines. Mating habitat usually is one or several small, shallow, open-water ponds.

(2) Nesting (March to May). Mallards, teal, and black ducks nest on the ground, usually within 150 yards of water, but sometimes farther away in medium-height vegetation, such as alfalfa, redtop, and other grasses as well as emergent type wetland grasses, sedges, and rushes. Wood ducks nest in trees along water or waterways where they prefer a hollow or natural cavity in the trunk.

(3) Rearing the broods (May to early September). Immediately after the young are hatched, the hen leads them from the nest to a water area several feet deep, surrounded by or interspersed with marsh plants, such as bulrushes, sedges, cattails, and other aquatic plants. Wood ducks desire woody cover along streams or ponds.

(4) Loafing. Ducks spend a great deal of their time loafing, sunning, or preening themselves on mud flats, knolls, or small islands. Wood ducks commonly perch in trees.

(5) Feeding. Black ducks, mallards, teal, and wood ducks feed primarily on plant seeds. They occasionally take snails, insects, and herbaceous vegetation. Important plants are corn, buckwheat, sorghum, barley, pondweeds, wildrice, millets, bulrushes, smartweeds, naiad, and white and pin oak acorns. Water, of course, is an essential element of the habitat.

Swamp or marsh areas, 1 acre and larger, are more valuable.

The following water conditions are desirable on feeding a and brood rearing areas: At least 50 percent of the area with water less than 3 feet deep; small (500-2,000 square feet) open-water areas scattered throughout, about 5 per acre.

b. Muskrats

Muskrats are semi-aquatic and need water to live. The entrance to muskrat houses (or dens) is normally 4 to 16 inches beneath the water level. Muskrats use open water for travel, and their diet is composed chiefly of leaves and roots of emergent and aquatic vegetation.

c. Wading Birds - Consideration is given here to four families of birds:
Ardeidae (Herons and Bitterns); Ciconiidae (Storks and Wood Ibises); Threskiornithidae (Ibises and Spoonbills); and Gruidae (Cranes).

Obviously, many species of wildlife, such as other water birds -- amphibians, reptiles, fishes, and some mammals, particularly the marsh and swamp dwellers -- benefit from management of wading bird habitat.

The wading bird group feeds largely on small aquatic life found along edges and in extensive shallows of lakes and swampy areas. All kinds of small fish, both game and rough fish, have been found in food habitat studies. Salamanders, frogs, and aquatic insects make up a part of the diet. Sluggish swimmers and prolific producers, such as gambusia (top minnows), make good food sources.

Herons and the like usually nest in groups of a few to several hundred or more. These rookeries may have several species nesting in one tree. The nesting birds prefer to build over water several feet deep. Cypress swamps with enough underbrush, such as buttonbush, make desired nesting sites.

It is generally believed that water fluctuation plays an important role in nesting behavior. Plentiful water supply in early spring apparently stimulates breeding. Low water levels concentrating the food source 4 to 6 weeks later provide good feeding conditions when the young are in the nest.

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